U. S. DEPARTMENT OF AGRICULTURE
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CONTROL OF THE CODLING MOTH IN THE PACIFIC NORTHWEST

THE CODLING MOTH is at present the most serious insect pest with which the apple and pear growers of the Pacific Northwest have to contend. Losses from "worms" in some years average as high as 20 per cent of the total crop, and losses sustained by individual growers are often more than 50 per cent of their crops. On the other hand, by using proper methods, many growers keep their losses well below 5 per cent. A knowledge of the habits of the insect is essential for the intelligent application of control methods.

This bulletin briefly describes the various stages of the codling moth and gives an account of its habits. A pictorial diagram of the life cycle is given in Figure 6. Detailed spraying instructions are set forth and other control methods are suggested. Combined spray schedules will be found at the end of this bulletin, showing how the apple powdery mildew and scab sprays may be combined with the codling moth sprays.

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CONTROL OF THE CODLING MOTH IN THE PACIFIC NORTHWEST.

By E. J. NEWCOMER, *Senior Entomologist*, M. A. YOTHERS, *Associate Entomologist*, and W. D. WHITCOMB,[1] *Assistant Entomologist, Division of Deciduous Fruit Insects, Bureau of Entomology.*

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LOSSES DUE TO THE CODLING MOTH.

THE CODLING MOTH[2] is the most serious insect enemy of apples and pears in the Pacific Northwest, taking the region as a whole. Estimated losses from this insect alone run as high as 20 per cent of the total crop of the region in some years. This loss is in spite of the fact that practically all of the growers spray their trees with arsenate of lead from one to six times every season. It is obvious that there is need of improvement, both in the timing of the sprays and in the methods of application. Many growers are consistently keeping their losses from this insect below 5 per cent annually, and others can do as well by following the proper methods.

NATURE OF INJURY.

The larva or "worm" is the only stage of the codling moth which is injurious, and the only injury of consequence is to the fruit. The young worms, upon hatching from the eggs, seek out the nearest fruit and burrow into it, producing the familiar wormy apple or pear (see title page). A fruit in this condition, though not totally ruined, loses most of its commercial value, since it will not keep long, and the laws of some States forbid its being shipped, except to by-products plants. The value of such fruit, on the average, is not more than one-eighth of the value of sound fruit. It therefore pays to produce sound apples and pears.

DISTRIBUTION AND FOOD PLANTS.

The codling moth is found in practically all localities where apples or pears are grown. No place where these fruits can be raised may be said to be immune, though some sections, particularly the newer ones, are not yet seriously troubled with it. Isolated orchards are

[1] Resigned Aug. 31, 1925.

[2] *Carpocapsa pomonella* L.

perhaps the safest from attack, if care is taken not to introduce worms in fruit or boxes, or in other ways. The codling moth does not spread rapidly by itself.

In the cooler regions the worms will probably never be as serious as in warmer regions. This is because the shorter season causes more of the first brood of worms to delay transforming to moths until the following year, resulting in a smaller second brood.

The apple is the preferred food of the codling moth, and by far the greatest injury is suffered by this fruit. Some varieties are more susceptible than others. The Winesap and Arkansas Black are attacked less, while some of the more fragrant varieties, such as the Spitzenberg and the Delicious, are preferred. Summer varieties, which ripen while the worms are still active, are always more wormy than the late varieties. Crab apples are infested somewhat.

FIG. 1.—Codling moth, enlarged; inset, natural size.

Pears are also attacked by the codling moth to a great extent, early varieties, such as the Bartlett, being favored. Pears are hardier than apples, and where the two are grown together the insect much prefers the apples. Pears grown in considerable acreages by themselves, however, often become nearly as badly infested as apples.

In addition to apples and pears, the codling moth has been recorded as infesting peaches, cherries, plums, prunes, quinces, and apricots. These infestations are of little consequence, usually occurring where such varieties are interplanted with badly infested apples. In recent years, walnuts have become infested in some parts of California, but in the Northwest the limited plantings of walnuts have not yet shown signs of injury.

APPEARANCE AND HABITS OF THE CODLING MOTH.

Successful control of the codling moth requires an ability to recognize the insect in its different stages.

THE MOTH.

The adult insect, which is seldom observed by the orchardist, is a small, inconspicuous moth (fig. 1). The female is usually a little

larger than the male, and has a maximum wing spread of about three-fourths of an inch. The front or upper wings are brownish gray, crossed with lines of lighter gray, and have a bronze band at the tip. The hind wings, which are covered when the moth is at rest, are grayish brown. The average length of life of the moths is two weeks.

The moths feed very little and begin to lay eggs in one or two days after they appear, if the weather is favorable. The greatest activity occurs at dusk. Most of the eggs are deposited at this time, and only when the temperature is above 60° F. The number of eggs laid by each female varies greatly, but under favorable conditions the average is about 40. The eggs are deposited singly, those laid in the early summer being placed mostly on the leaves and twigs, while later many of the eggs are found on the fruit.

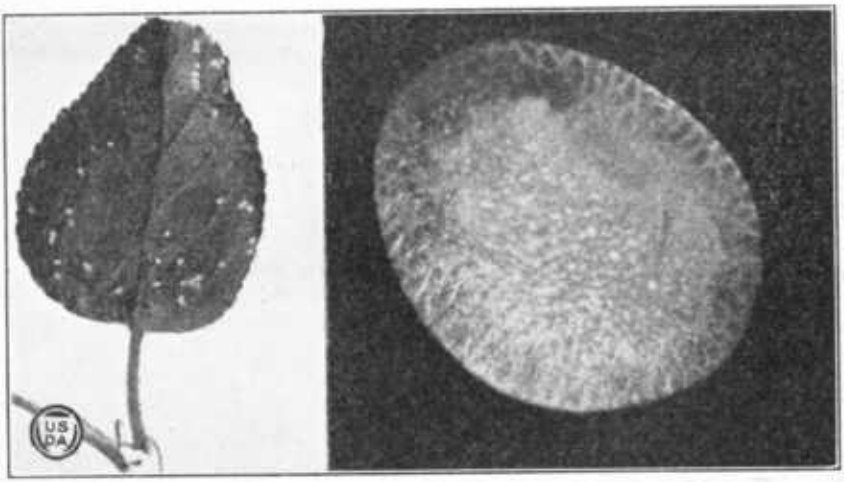

FIG. 2.—Codling moth eggs: Left, natural size, on apple leaf; right, single egg, much enlarged.

Codling moths are capable of flying half a mile or more. In orchard sections, however, they do not ordinarily travel far, unless carried by the wind, as their object is to reach a tree on which to deposit eggs.

THE EGG.

The pearly white egg is about the size of a pinhead and resembles a thin convex disk (fig. 2). A few days after the egg is laid, a red ring, the germ band, becomes apparent, and the day before the worm hatches, a black spot, the head of the worm, is easily seen. The eggs are extremely sensitive to temperature. High temperatures will hatch the worms in 5 days, and cool weather has retarded the incubation for as long as 23 days. The average incubation period is about 10 days.

THE LARVA OR WORM.

It is the larva or worm of the codling moth that feeds on the fruit, and in this stage it is most susceptible to control measures. All fruit growers are familiar with the pink or white worm, about five-

eighths of an inch long, which is the full-grown larva of the codling moth (fig. 3). Immediately after hatching from the egg, the young worm, scarcely one-eighth of an inch long, with a black head appearing too large for its slender body, begins a very active search for food. It never enters the fruit beneath the shell of the egg, but emerges from a hole broken in the upper side of the eggshell near the edge. It then crawls rapidly about, until a suitable place of entrance into the fruit is found. The calyx cup, the stem cavity, or an injury to the skin of the fruit is preferred, as it affords protection and an easy entrance. Many worms of the summer broods burrow directly into the side of the fruit. In about 1½ hours the worm has eaten through the skin, excavated a cell just beneath the surface, and covered the entrance hole with frass which is held together with silken threads.

FIG. 3.—Larva and pupa of codling moth, in cocoons. Twice natural size.

For a few days the worm feeds near the surface, or in the outer cavity of the calyx, before burrowing to the center of the fruit, where it remains, often feeding on the seeds, until it is full grown. When of full size it makes an exit tunnel to the surface, from which it soon leaves the fruit and seeks a place to spin its cocoon. The exit hole is ordinarily more evenly rounded and larger than the entrance hole.

If the young worm dies from the effects of poison, is killed by predacious enemies, or leaves the entrance hole for any reason before it has burrowed more than one-eighth of an inch from the surface of the fruit, the resulting injury is called a "sting" (fig. 4). Because of the hard flesh and smooth skin of pears, worms attacking this fruit enter at the calyx or at the stem end more often than in apples. When a worm enters the side of a pear, the characteristic surface feeding is usually absent and the small entrance hole has the appearance of an unhealed sting. Occasionally larvæ are seen burrowing into the veins of leaves and the terminal shoots of twigs, but they seem unable to develop to maturity on food of this kind.

THE COCOON.

The tough, waterproof cocoon (fig. 3) is woven of white silken threads with which bits of bark, wood, and leaves are often mixed. Cocoons are spun in any protected place, and are more commonly found about the tree under rough pieces of bark and in cracks or wounds in the branches and trunk. They also occur about the packing sheds, in cracks in the floor and walls, and in corners of boxes and barrels. Many worms spin their cocoons in the ground near the trunk of the tree.

THE PUPA.

While undergoing the changes from worm to moth, the insect is called a pupa (fig. 3). At first this is amber colored, changing

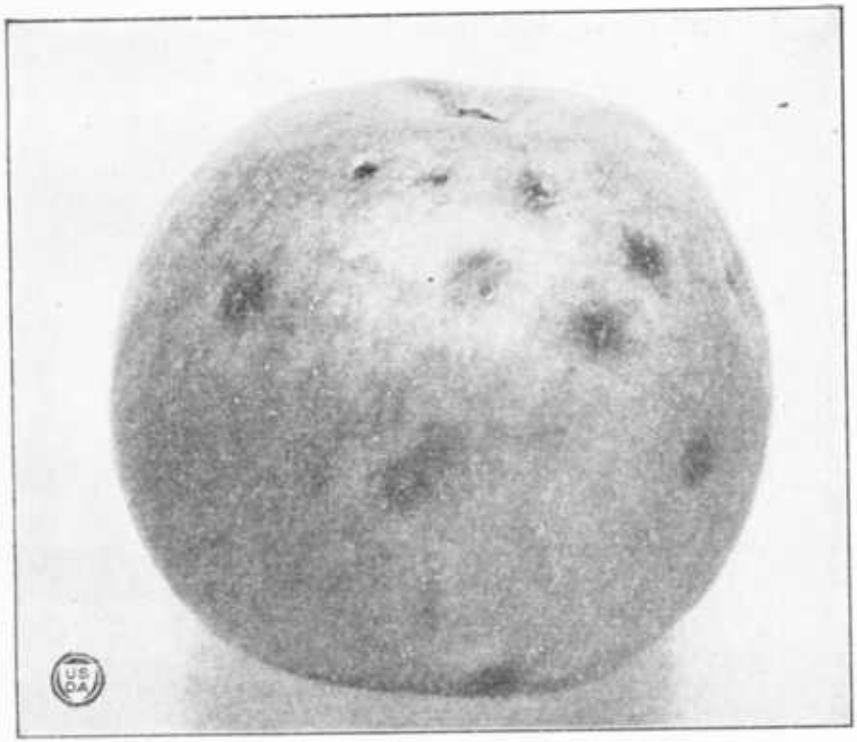

FIG. 4.—"Stings" produced by codling moth worms on apples.

later to a dark brown. When the necessary changes have taken place, the pupa wriggles its way out of the cocoon, the pupal case splits at the front, and the moth emerges. The empty pupal cases are frequently seen in the orchard protruding from cocoons (fig. 5).

SEASONAL HISTORY.

In order to control the codling moth, it is essential to understand the seasonal history of the pest, not only in general, but also under local conditions. The pictorial diagram given in Figure 6 will aid in following its activites through the season.

WINTERING WORMS.

The codling moth spends the winter as a worm in a cocoon. The wintering worms include all of the last brood of worms which develops during the year, and a part of the preceding brood, the percentage of wintering worms of the earlier brood being the smaller.

SPRING PUPÆ AND MOTHS.

With the coming of warmer spring weather, the wintering worms change to pupæ and later to moths, the latter beginning to appear soon after the apple trees have bloomed. The pupæ and moths which develop from the wintering larvæ are called the "spring brood of pupæ" and the "spring brood of moths." The moths of the spring

FIG. 5.—Empty pupal cases of codling moth protruding from cocoons at base of tree.

brood, under normal conditions, reach the height of their activity in the Pacific Northwest during the last week in May or the first week in June. When the temperature in the late afternoon or evening is 60° F. or higher, the moths lay eggs.

The dates given in Figure 6, as well as those in the text, are only approximate and will vary with the locality and season.

FIRST GENERATION.

The first generation begins with the eggs laid by the spring brood of moths and includes the worms, pupæ, and moths resulting from them. The earliest eggs are commonly subjected to considerable cool weather and the worms are not hatched for 12 to 14 days. As the temperature becomes higher, the length of the incubation period of the egg decreases, the minimum being 5 days. Newly hatched worms of this generation, that is, the first-brood worms, are found

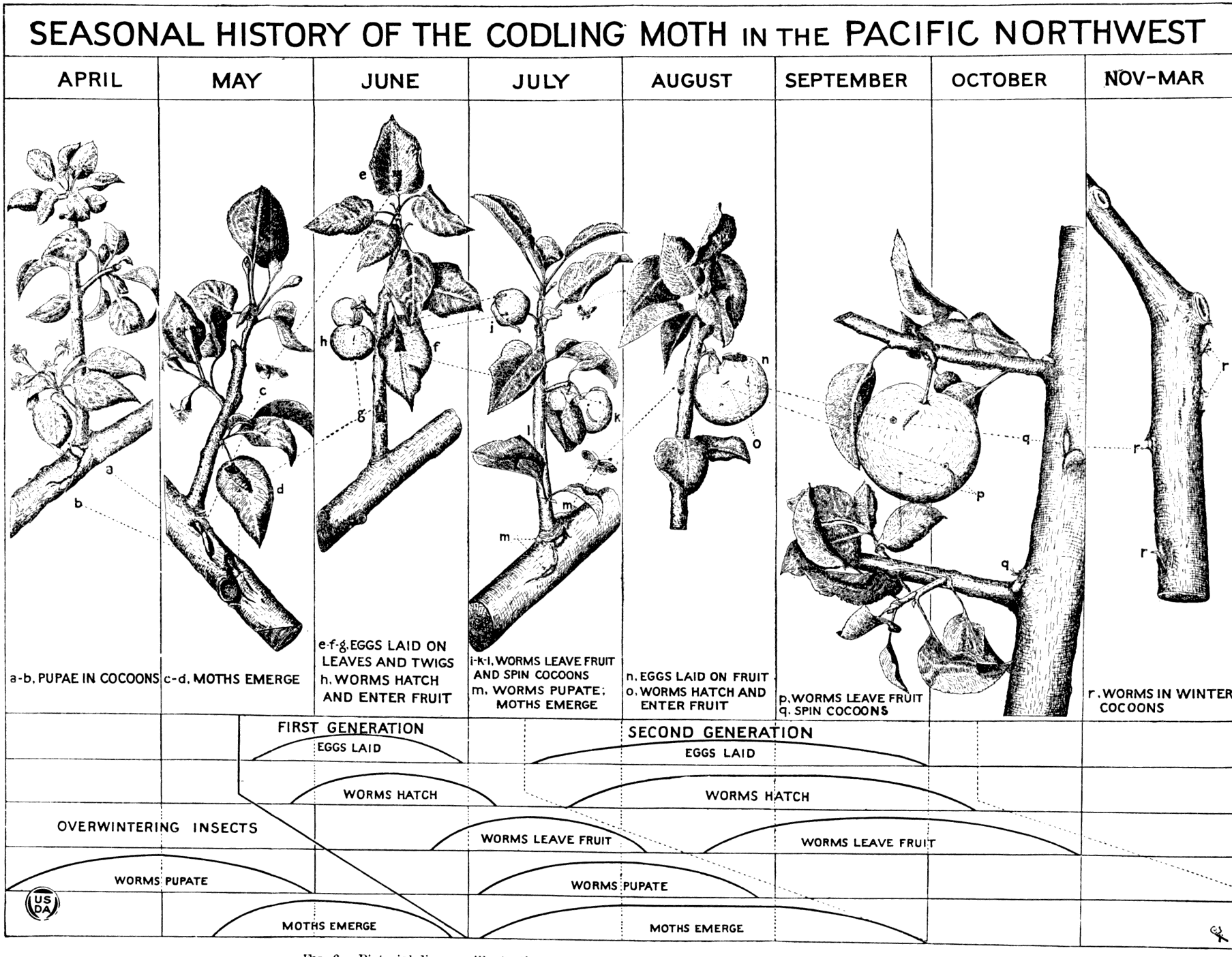

FIG. 6.—Pictorial diagram illustrating seasonal history of the codling moth in the Pacific Northwest.

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entering the fruit for a period of about five weeks, and are most numerous about the middle of June.

The worms constituting the first brood feed in the fruit for about three weeks. Then, having reached their full growth, they leave the fruit and busy themselves for five or six days in making their cocoons. About 75 per cent of these worms continue their development into pupæ and moths, but the others remain in their cocoons until the following season. With the higher temperatures, the worms that transform pass through the pupal period in about two weeks, less than half the time required by the pupæ constituting the earlier spring brood.

The first individuals of the first brood of moths appear early in July and after this time moths are present in large numbers until cool weather, a period of about 10 weeks. The complete life cycle of the first generation, from the time the egg is laid until the resulting moth is prepared to lay eggs, is accomplished in 50 to 60 days.

SECOND GENERATION.

Many eggs of the second generation develop in six or seven days, and the young worms, appearing first about the middle of July, continue to attack the fruit in large numbers for about six weeks. These second-brood worms remain in the fruit to feed for a longer time than do the worms constituting the first brood, their average feeding period being about a month, and most of them will not change to pupæ and moths until the next season.

After leaving the fruit, the worm chooses its winter quarters and spins a cocoon. In the Rogue River Valley of Oregon and in some parts of eastern Washington a small number of these worms pupate and develop into moths of the second brood, which deposit a few third-brood eggs.

OVERLAPPING OF GENERATIONS.

The lower half of Figure 6 shows the average period which is covered by each stage of the codling moth. At certain times all stages are present, owing to the overlapping of generations. The first generation is the most uniform and is completed by the largest number of individuals. The stages of the second generation follow closely those of the first, though the corresponding stages of successive generations seldom overlap. Except for a short interval just before the middle of July, worms are hatching and attacking the fruit from the latter part of May to October.

NATURAL CHECKS ON CODLING MOTH INCREASE.

The worms of the codling moth while in their winter cocoons are subject to various unfavorable conditions. The weather is perhaps the most important of these. The worms will stand a great deal of cold, having been always accustomed to the same environment as the apple and pear trees. A temperature of a few degrees below zero will often kill 4 or 5 per cent of the worms not protected by snow or by the soil, and temperatures of 25° F. below zero or colder will kill practically all of the exposed worms. Many worms spin

their cocoons in the soil or near the soil surface, where they are ordinarily protected by snow, and even these very cold temperatures will fail to reduce the numbers of worms materially. More worms will be killed by alternating periods of freezing and thawing than by a long period of freezing weather. In the spring unfavorable weather may hinder the development of the codling moth. Cold weather during the time the moths are flying may prevent them from depositing as many eggs as in warm weather. Birds also have a part in destroying the wintering worms.

At the present time insect enemies of the codling moth apparently are not of any great importance in the Pacific Northwest. A few beetles prey on the worms, and occasionally some eggs are found to be parasitized by a minute four-winged fly,[3] but for the most part the codling moth is free from attack by other insects.

IMPRACTICAL MEASURES FOR CONTROL.

Since many valueless methods for the control of the codling moth are continually being proposed, it seems necessary to mention some of them here in order to show why they are of no practical use.

Trap lights.—Trap lights are frequently suggested to catch the moths. They are worthless for the reason that the codling moth is not attracted to lights to any extent. In this respect it differs from many of the night-flying cutworm moths, which may be attracted to lights in numbers.

Untried spray materials.—Fruit growers should avoid the use of new and untried sprays, for in the great majority of cases these prove worthless.

Cultivation.—Since many codling moth larvæ enter the soil to spin their cocoons, it has been thought that cultivation would be of some value in destroying these. The evidence at hand tends to show that the great majority of these worms enter the soil at the tree trunk and spin their cocoons in contact with the trunk or larger roots. It would therefore be impracticable to destroy any of these cocoons by cultivation. Clean cultivation of an orchard has no effect in reducing the number of worms.

METHODS OF CONTROL WHICH SUPPLEMENT THE USE OF SPRAYS

Planting and pruning.—From the standpoint of codling moth control it is advisable, when setting out a young orchard, to plant each variety in blocks of from four to six rows, rather than in alternating rows. This will make it possible to spray the earliest varieties first, and the others later, and will facilitate handling the fruit. Trees should be planted at such a distance apart that the spray machine can be driven between the rows at any time. The branches of adjacent trees should never interlock, as this interferes with thorough spraying. When the trees are pruned, the necessity of subsequent spraying should be considered, and the trees kept open enough to permit all parts to be reached with the spray. The

[3] *Trichogramma minutum* Riley.

tops of high trees are very difficult to spray properly, as well as expensive to pick. Consequently, trees should not be allowed to grow to extreme heights.

Thinning the fruit.—Many if not most of the first brood of worms that escape being poisoned by the spray may be destroyed by proper thinning of the fruit. All clusters should be thinned to one fruit, preferably the largest, as the worms find it much easier to enter where two fruits are touching, and usually both fruits are damaged. All fruits already wormy should be removed, and these should not be dropped to the ground, but should be destroyed. This wormy fruit may be fed to hogs, or thrown into a barrel or tank of water to which a little fuel oil has been added, or it may be burned, or buried under 6 inches of closely packed soil.

FIG. 7.—Apple orchard with trees banded for the codling moth.

To destroy the maximum number of worms, thinning should be done early—that is, in June—because the worms begin leaving the fruit during the last week of June. If the thinning is delayed until July, many of the worms will have left the fruit and will escape destruction. Early thinning is good orchard practice for other reasons, as it relieves the trees of the unnecessary load at the earliest possible time, and gives the remaining fruit a better chance for development.

Banding the trees.—Banding the trees with cloth bands in order to catch the worms has long been practiced, and this method of control has its uses (fig. 7). *Banding should never take the place of spraying*, but it is often a valuable help in reducing the number of worms in a badly infested orchard. Under the most favorable conditions, not more than one-third of the total number of worms will be caught in bands, and in orchards where the worms are being held in check effectively by spraying and thinning, banding is a useless expense.

To make banding most effective, the trees should first be scraped very thoroughly to remove all the loose bark under which cocoons might be spun. This should be done during the winter or early spring, when many wintering worms will be destroyed. A triangular box scraper or an old, well-sharpened hoe with a short handle may be used, or a suitable tool may be made from a mower section (fig. 8). All dead wood should be removed, and all cracks and holes filled up as far as possible. This will force more of the worms to spin their cocoons under the bands. Care should be taken not to scrape off the live bark.

The bands may be made of any heavy cloth, burlap from old sacks being perhaps the most available and satisfactory material. Strips should be cut a foot wide and long enough to extend once around the trunk and overlap a little. These strips should be folded lengthwise, making a band about 6 inches wide. The bands are held in place by finishing nails or other nails with the heads nipped off. One or two of these nails should be driven into the tree where the ends of the band overlap, leaving only enough of the nail protruding to hold the band nicely.

These bands must be in place by the middle of June. Beginning July 1, and every 10 days thereafter until September 1, the bands should be removed from the trees and examined, and all worms and pupæ found in the bands or on the trunks of the trees destroyed. Worms coming into the bands after this date remain there for the winter, and it is not necessary to remove them until the fruit has been harvested. At any convenient time after harvest, the bands should again be removed and all worms destroyed. The bands may then be put away for the winter to be used again the following season. If it is desired to catch only the wintering worms, the bands should not be put on the trees until August 1, and a single examination after harvest is all that is necessary. Chemically-treated bands have been developed that kill most of the worms entering them and make periodical examination unnecessary.[4] Banding should not be practiced unless these treated bands are used or unless the grower examines the untreated bands systematically as recommended.

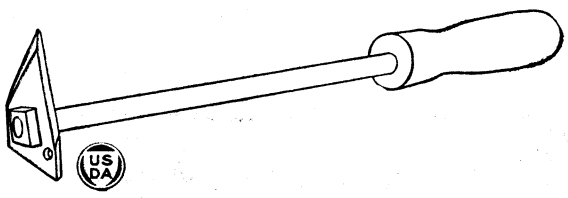

FIG. 8.—Scraper for removing bark from trunk of apple tree preparatory to applying band.

Baits.—Various baits have been tried, such as cider, vinegar, molasses, and fermented apple juice, placed in pans or jars in the tops of the trees. Recent tests of these baits have shown that considerable numbers of codling moths are attracted to a mixture of molasses and water and to fermented apple juice. The use of a few of these baits in an orchard will show the grower when the codling moth first appears in the spring, and will give him an idea of the relative abundance of the moths during the season. Their use in large numbers in the orchard may also have some value as a supplementary control measure.

[4] Information as to how to make and use these treated bands may be obtained from the Bureau of Entomology, U. S. Department of Agriculture.

DUSTING OUTFITS.

A small acreage of young trees or a few trees about the house may often be most conveniently treated for the codling moth by using a mixture of dry powdered lead arsenate and hydrated lime in a hand duster. Power dusters are on the market for large operations, but dusting is not recommended for the commercial orchards of the Pacific Northwest.

SPRAYING THE MAIN RELIANCE FOR CONTROL.

The efficacy of spraying the fruit to protect it from the codling moth is so great that this method of control far outweighs in importance all the other methods put together. The maximum efficiency in spraying for the codling moth is not as easily attained as in spraying for other pests, because more sprays are necessary, and the time of application is of more importance. Hence careful work is required.

EQUIPMENT FOR SPRAYING.

SPRAYING OUTFITS.

No commercial orchardist should be without a power spraying outfit. It is usually an expensive matter to hire the spraying done;

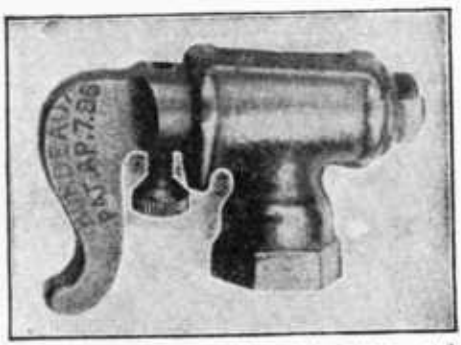

FIG. 9.—Bordeaux nozzle. (Quaintance and Siegler.)

FIG. 10.—Angled nozzle of the eddy-chamber or whirlpool-disk type. (Quaintance and Siegler.)

the work is slighted or done at the wrong time, and the results are poor. Often adjacent growers with small acreages can combine in the purchase of an outfit, and spray their orchards jointly. The number of acres a single outfit can cover will depend on the type of outfit, distance to water, efficiency of the operators, size of trees, and the lay of the land. It should be possible to apply an average of 8 to 10 tanks of spray in a 10-hour day. In general, enough outfits should be provided to complete any particular application of spray in a week or 10 days.

Many types of outfits are on the market, and the grower has a wide variety to choose from. Spray outfits usually receive severe treatment and a machine should be purchased that is known to be durable and as free as possible from mechanical faults. The engine on the machine should be of sufficient horsepower to operate the pump easily. An engine that is too small will cause a great deal

of trouble. In deciding on the size of the machine, the grower must be guided largely by the size of his orchard. Some of the larger outfits are giving very good service and are undoubtedly worth the added cost to the man who has a large orchard.

Stationary systems for spraying are rapidly coming into favor, and are worthy of investigation by the fruit grower who does not already use one. Pipes are laid in the orchard at suitable intervals, with frequent outlets to which the hose may be attached. These pipes are connected to a pump which is housed at some convenient point and is operated by a gasoline engine or an electric motor. The initial outlay is relatively great, but the system should last longer than the usual outfit, because it is free from wear and tear caused by hauling about the orchard and over irrigation ditches. The use of a stationary system also makes it possible to spray any part of the orchard at any time, weather permitting, regardless of the condition of the soil, load on the trees, presence of props, or other things that sometimes interfere with driving a portable outfit through the orchard.

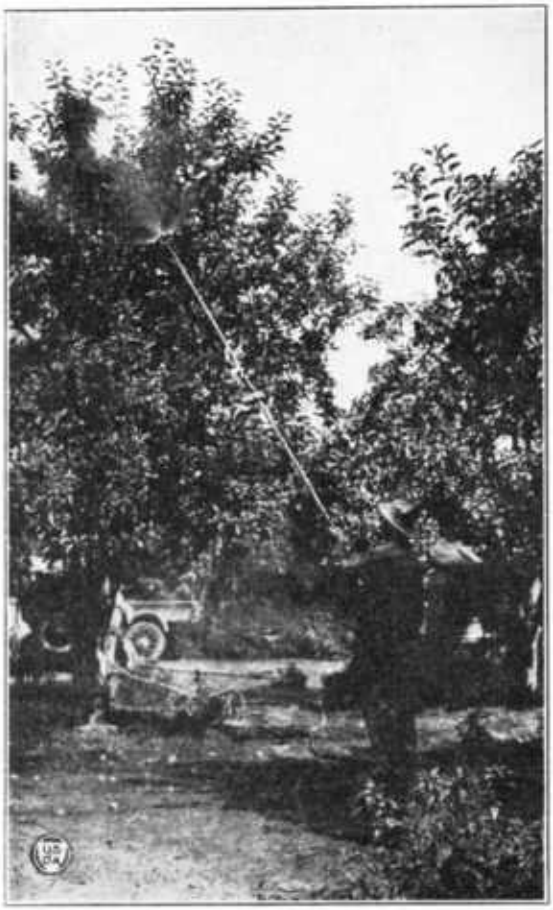

FIG. 11.—Spray rod equipped with two angled nozzles on a Y.

ACCESSORIES.

The spray hose should be of the best grade, preferably one-half inch inside diameter, and it is most conveniently handled if in lengths of 50 feet. Couplings and clamps should be heavy and properly adjusted so that there will be no leaks and no danger of coming apart. For most spraying operations two leads of hose are used. Three leads may be employed where one operator sprays from the tank or tower. Four leads are likely to be inconvenient, as the operators get in each other's way.

Either spray guns or rods and nozzles may be used in spraying for the codling moth. Good results will be obtained with either if they are properly used. Spray guns are used almost altogether, however, as they are lighter and more easily handled than the rods. Spraying is more rapid with the guns and hence more economical, but careless work is more likely to be done than with the rods. The spray guns have the advantage of being adjustable, so that a wide cone of spray may be used for close-range work, or a long stream for greater distances (figs. 16 and 17). This adjustable feature should be utilized, the aim being at all times to reach the fruit to be sprayed and no farther. In purchasing a spray gun, one should be chosen in which the adjustment is made by a short turn of the handle. Durability should also be considered, as some spray guns get out of order easily. The disks for the guns and for the whirlpool nozzles come with different-sized holes, and the size to use will depend on the pressure supplied by the pump. New disks should be substituted when the holes in the old ones wear too large.

FIG. 12.—Power sprayer equipped with a tower. (Quaintance and Siegler)

The tops of large trees, when sprayed from the ground, are often very poorly sprayed. In order to do more thorough work a tower (fig. 12) may be used on a portable sprayer. This may be of wood or iron, and with a platform surrounded by a railing or with a frame in the shape of a carpenter's horse which may be straddled by the operator. If all the spraying is done from the ground, which is necessary when stationary systems are used, particular care should be taken to spray thoroughly the tops of the trees.

SPRAY MATERIALS.

LEAD ARSENATE.

Lead arsenate is the standard insecticide used in spraying for the codling moth. At present no other insecticide approaches it in effectiveness or safety. Its chief fault is that it is a rather slow-acting poison. The codling moth worm burrows into the fruit in a short time, and even though it consumes a killing dose of poison in doing so, a "sting" (fig. 4) is produced before the worm dies. These stings are undesirable, as they lower the grade of the fruit. No insecticide has been found that will kill the worms so quickly that they are unable to produce stings. The only way to avoid stings is to keep the number of worms down to a minimum.

Lead arsenate may be procured in either the powdered or the paste form. One form is as effective as the other, but the powder is more commonly used, as it is more convenient to handle and may be stored without danger of freezing. It does not lose its strength if kept from one season to another. According to the Federal insecticide act of 1910, lead-arsenate paste must contain at least 12.5 per cent of arsenic pentoxide (As_2O_5), and since the paste is usually nearly 50 per cent water, the powder should have at least 25 per cent of arsenic pentoxide. In fact, most brands on the market contain about 30 per cent, and a statement of the arsenic content appears on the package. The insecticide act practically insures that any brand of lead arsenate which has been on the market for some time and enters into interstate commerce contains the required amount of poison.

FIG. 13.—Apple oversprayed until coarse drops have formed

For the codling-moth spray use the powdered lead arsenate in the proportion of 2 pounds to 100 gallons of water, washing it into the tank through a sieve while the tank is being filled. Weaker dilutions should not be used, but 3 pounds to 100 gallons of water may be used in the calyx and early cover sprays for more effective control.

The use of more than 2 pounds to 100 gallons in later sprays should be avoided, as such use would tend to increase the difficulty of spray residue removal. If the paste lead arsenate is used, the quantities should be doubled, and the required amount should first be mixed with a small quantity of water and worked into a thin paste before being put into the tank.

OTHER ARSENICALS.

Calcium arsenate, magnesium arsenate, manganese arsenate, and Paris green have been used as codling-moth sprays, but they are not so desirable or so safe for use on the foliage as the lead arsenate.

OIL EMULSIONS.

Mineral-oil emulsions form a valuable addition to the lead-arsenate spray program. These oils kill the eggs and cause the lead arsenate

to adhere more firmly to the fruit and foliage. For this purpose, emulsions containing oils ranging in viscosity from 65 to 75, and with a sulphonation test of not less than 85, should be used. It is preferable not to use oil at all on Yellow Newtown and certain other yellow varieties of apples susceptible to oil injury, although oil with a viscosity of not more than 55 may be used.

In general an oil emulsion should not be used with more than three lead arsenate sprays on account of danger of injuring the trees or reducing the size of the fruit. Neither, for the same reason, should it be used within two months of any lime-sulphur spray. No oil emulsion should be used with lead arsenate in the second-brood sprays because such use materially increases the difficulty of removing the spray residue. For these late sprays a combination of oil emulsion and nicotine sulphate has been found to be effective. Whether combined with lead arsenate or with nicotine sulphate the oil emulsion should be used in the proportion of 1 gallon to 100 gallons of spray. The nicotine sulphate should be used in the proportion of one-half to two-thirds of a pint to 100 gallons of spray.

FIG. 14.—Apples sprayed with lead arsenate to which a casein spreader has been added

When using an oil emulsion with lead arsenate, the emulsion should be put in the tank first, the water turned in, and the lead arsenate added just before the tank is full. Such combinations should be applied immediately after being mixed, as difficulty may be experienced in cleaning fruit sprayed with a mixture that has been allowed to stand for some hours.

SPREADERS.

The mixture of lead arsenate and water, when sprayed on the fruit and foliage of a tree, does not spread as evenly over the surface as is

desirable. The liquid tends to collect in drops (fig. 13) and much of it rolls off altogether. To overcome this, certain materials may be added to the spray in the tank which will cause the spray to spread and wet the surface more thoroughly (fig. 14). These materials are known as spreaders.

The use of spreaders in codling-moth spraying is relatively new, and there is much to be learned regarding them. So far as known at present, a spreader is a desirable addition to the lead-arsenate spray. It is possible to control the insect just as thoroughly without a spreader as with it. It is somewhat easier, however, to give the fruit a complete coat of poison when a spreader is included. Without a spreader, the tendency is to overspray; that is, spray until the material collects in relatively large drops, with areas between the drops partially or completely unprotected. With a spreader there is no difficulty in completely covering all parts of the fruit that are hit by the spray.

FIG. 15.—Spraying the inside of a tree with a spray gun.

The spreader will not cause the spray to spread around to the opposite side of a fruit. The opposite side must be sprayed. Neither can a spreader be depended on to make the material go farther. The addition of a spreader to the lead arsenate has the advantage of eliminating the conspicuous white blotches that usually appear on fruit sprayed with the arsenical alone (fig. 13). These interfere with the proper coloring of the fruit, and sometimes make it objectionable to prospective purchasers. Chemical analyses show that there is just as much poison on an apple when a spreader has been used as when it has not. The difference is that the poison is more evenly distributed.

Spreaders are also a desirable addition to the combination of oil emulsion and lead arsenate, often preventing injury that might otherwise occur.

HOW TO SPRAY.

The equipment for codling moth spraying usually includes two leads of hose. The spraying outfit is driven down the middle between two rows of trees and each operator, working from the ground, sprays one row, spraying each tree on all sides. Where trees are closely planted it is often possible for each man to spray two rows of trees, but in all cases each tree should be completely sprayed before another one is started. This reduces to a minimum the chances of missing whole trees or parts of trees.

FIG. 16.—Spraying the top of an apple tree with a spray gun.

Where the trees are high enough to demand the use of a tower, it is necessary to have a third operator, or to have one on the tower and one on the ground (fig. 12). In either case, the man on the tower sprays the upper part of each tree, and the man or men on the ground spray the lower part.

In spraying trees for the codling moth, particular attention is paid to the fruit. The foliage need not be completely covered unless the spray is being applied also for the powdery mildew, for scab, for aphids, or for other leaf-inhabiting pests. Too much emphasis can not be placed on the necessity of thorough work. The operator should commence by spraying the fruit on the inside of the tree (fig. 15), standing close to the trunk. He should then spray the outside fruit, starting at any convenient point and going completely around the tree.

Each fruit should be sprayed from at least two sides, as the spray will not creep around the fruit even when a spreader is used. It is impossible to spray more than two-thirds of a fruit from any one point. If no spreader is used, spray until the fruit is thoroughly covered. Some material will be wasted by its dropping to the ground but this is unavoidable. The use of a spreader makes it somewhat easier to obtain a complete covering of the fruit (fig. 14). Pay particular attention to the fruit in the tops of the trees (fig. 16). The mist which a gun throws out between the operator and the top of the tree often deceives him. When spraying the lower limbs with a gun, it should be adjusted to produce a wide cone of misty spray which will just reach the fruit (fig. 17).

FIG. 17.—Spraying the lower limbs of an apple tree with a spray gun.

The pressure necessary will vary with the equipment. Whether nozzles or guns are used, sufficient pressure should be supplied to form a fine mistlike spray, particularly for the cover sprays. If enough pressure can not be supplied to do this, the number of nozzles used, or the size of the holes in the disks, will have to be cut down until this type of spray is produced. With the the smaller nozzles a proper spray will result with less than 200 pounds pressure. With guns and large-holed disks, 300 or more pounds may be required.

The quantity of spray necessary to spray a tree thoroughly varies greatly. In general, a thrifty 15-year-old apple tree with a full crop of fruit will require from 10 to 12 gallons of spray for the calyx application and from 8 to 10 gallons for the cover applications.

WHEN TO SPRAY APPLES.

It is of the utmost importance that the various codling-moths sprays be applied at the proper time, since a spray applied at the wrong time may be largely wasted and the fruit may be left unprotected when large numbers of worms are hatching. It is more difficult to ascertain

the proper time for applying these sprays than for any of the other sprays used by the fruit growers of the Pacific Northwest, as the time differs from year to year.

The various other orchard operations, such as irrigating, cultivating and thinning, should not be allowed to interfere with the spray schedule. The handling of alfalfa in the orchard often seriously disrupts the spraying program. This should not be permitted. The best orchard practice does not favor cutting alfalfa for feed. This procedure removes valuable tree food from the orchard. If the alfalfa is cut, it should invariably be cut and removed from the orchard just prior to an application of spray, regardless of its condition for hay, thus obviating danger of poisoning stock. The alfalfa as a crop is secondary in importance to the fruit.

CALYX SPRAY.

The calyx spray is applied for the purpose of poisoning the calyx cups or blossom ends of the apples, in readiness for the worms of

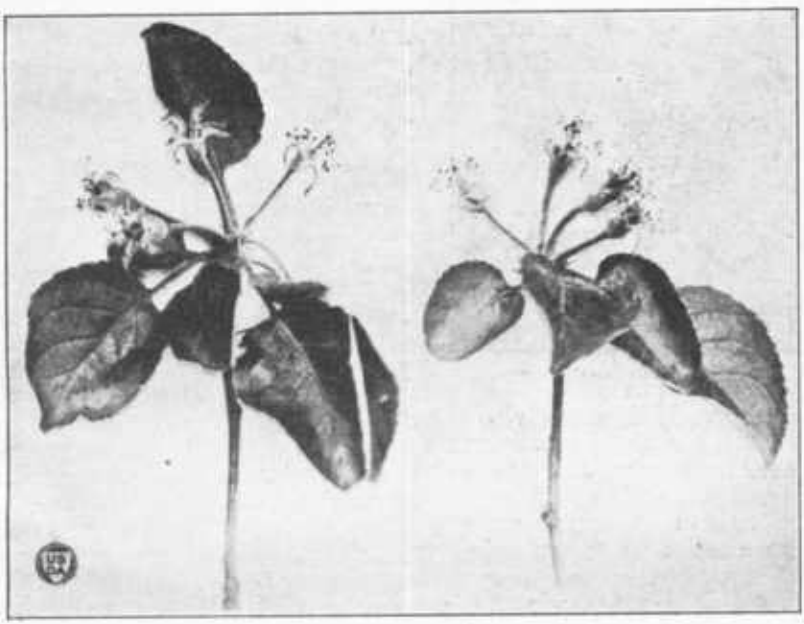

FIG. 18.—Apple blossoms from which petals have just fallen; the right time to make "calyx spray" for the codling moth. (Quaintance and Siegler.)

both the first and second broods when they appear. Usually more than half of the total number of worms enter the apples through the calyx cups. This is the most important spray of all and should be very thoroughly applied, every calyx cup being filled. Some growers consider it advisable to apply two calyx sprays, one right after the other, but if thorough work is done this is not ordinarily necessary.

The time to put on the calyx spray can best be determined by the individual grower. It must be applied between the time the petals fall and the time the calyx cups close, a period of not more than 10 days. Spraying should begin as soon as most of the petals have dropped (fig. 18), and should be completed before many of the calyx

cups have closed. It is often possible to spray the earlier blooming varieties first and then the later ones. *Do not spray while the trees are still in bloom, as injury may result to the blossoms or to the bees that visit them, and do not wait until the calyces have begun to close* (fig. 19).

COVER SPRAYS.

The cover sprays are for the purpose of coating the surface of the apples with poison to prevent worms entering the side. The number of cover sprays necessary will vary with the locality and the degree of worminess of the orchard. In the great majority of apple orchards in the Pacific Northwest five cover sprays should be used, three for the first brood and two for the second brood, following spray schedule 6 in Table 1. This procedure will be described first, and variations from it mentioned later. Every effort should be made to eliminate as far as possible the first brood of worms, and the spraying for this brood should be unusually thorough, even though few wormy apples are seen. The second brood of worms are all the progeny of the first brood, and the nearer the grower comes to eradicating the first brood the less trouble he will have with the second brood.

FIG. 19.—Too late for calyx spray

SPRAYS FOR THE FIRST BROOD.

First cover spray.—The first cover spray is put on to kill the earliest worms of the first brood, and is the most difficult to time properly. Most fruit growers are not equipped to make accurate observations of the habits of the codling moth, and can not tell in this way when to spray. If expert advice is not available, probably the best way to set this date is to observe the numbers of moths entering baits placed in the trees and also the 8 p. m. temperatures of a thermometer hung in the orchard away from the buildings. Begin making observations as soon as the calyx spray is completed, and when two or more consecutive nights occur with 8 p. m. temperatures of about 60° F. or higher, following the appearance of numbers of moths in the baits, plan to have the cover spray completed within 10 days. The reason for this is that these temperatures will cause the moths to lay eggs, as heretofore explained, and the eggs normally will hatch in about 10 days. The spray should be on the trees when the eggs are ready to hatch. This first cover spray will have to be applied almost invariably from two to three weeks after the calyx spray.

Second cover spray.—The second cover spray for the first brood should be completed 8 to 10 days after the first one has been finished. This spray is for the purpose of providing a fresh coating of poison at the time when the largest number of worms are hatching. Do not delay this spray longer than 10 days after the first cover spray.

The fruit is growing rapidly at this time and the worms are becoming more numerous. A delay may be costly. The second and third cover sprays may often be more accurately timed by keeping a record of the number of moths appearing in the baits.

Third cover spray.—The third cover spray should be completed about 10 days after the second one has been finished. Under most circumstances no further spraying will be necessary for the first brood of worms, but in very wormy orchards an additional cover spray for this brood may be applied to advantage.

SPRAYS FOR THE SECOND BROOD.

As there is an interval between the first and second broods of worms, there is no need of spraying again for about four weeks.

Fourth cover spray.—This puts the fourth cover spray, or the first spray for the second brood, about six or seven weeks after the first cover spray. This spray usually comes about the second or third week of July. If it is desired to time this spray more accurately, band a few wormy trees and spray 25 days after the first worm of the first brood appears under the bands. Unless the trees banded are quite wormy, however, this method will not be accurate. The influx of increasing numbers of moths in the baits during July will give an accurate indication of the need for second-brood spraying.

Fifth cover spray.—A fifth cover spray, or the second spray for the second brood, should follow the fourth at an interval of three or four weeks. These two applications should be sufficient for the second brood. If the worms are not under control by this time later sprays can do little good, and will only result in excessive quantities of residue on the fruit at picking time. If careful work is done in putting on the earlier applications there need be no apprehension of a sudden influx of late worms.

VARIATIONS IN THE NUMBER OF SPRAYS.

The number of sprays necessary to control the codling moth may vary from one to seven or more. At least half the total number of cover sprays, however, should be applied for the first brood of worms.

In certain favored localities in the Pacific Northwest, such as Whatcom County, Wash., the codling moth practically does not occur, and spraying may not be necessary. Farther south in Washington, west of the Cascade Mountains, the calyx spray alone may suffice (Table 1, schedule 1) or two sprays, the calyx spray and a cover spray about four weeks later (Table 1, schedule 2), may be required.

In the remainder of the Pacific Northwest, including Oregon, eastern Washington, and Idaho, the number of sprays necessary varies from one to seven, depending on the altitude, climate, degree of codling moth infestation, and other factors. Table 1 gives spray schedules calling for from one to six applications, and the individual grower will have to determine from his own experience and that of others in his locality which schedule to follow.

SPRAY SCHEDULES FOR APPLES.

TABLE 1.—*Codling moth spray schedules for apples in the Pacific Northwest.*

Schedule.	Spray.	Time of application.
Schedule 1 (1 spray)	1. Calyx spray	When most petals have fallen.
Schedule 2 (2 sprays)	1. Calyx spray	Do.
	2. Cover spray	4 weeks after 1.
Schedule 3 (3 sprays)	1. Calyx spray	When most petals have fallen.
	2. First-brood cover spray	4 weeks after 1.
	3. Second-brood cover spray	6 or 7 weeks after 2.
Schedule 4 (4 sprays)	1. Calyx spray	When most petals have fallen.
	2. First cover spray	3 weeks after 1.
	3. Second cover spray	2 weeks after 2.
	4. Third cover spray	6 or 7 weeks after 2.
Schedule 5 (5 sprays)	1. Calyx spray	When most petals have fallen.
	2. First cover spray	3 weeks after 1.
	3. Second cover spray	8 to 10 days after 2.
	4. Third cover spray	16 to 20 days after 2.
	5. Fourth cover spray	6 to 7 weeks after 2.
Schedule 6 (6 sprays)	1. Calyx spray	When most petals have fallen.
	2. First cover spray	3 weeks after 1.
	3. Second cover spray	8 to 10 days after 2.
	4. Third cover spray	16 to 20 days after 2.
	5. Fourth cover spray	6 to 7 weeks after 2.
	6. Fifth cover spray	10 or 11 weeks after 2.
Schedule 7 (7 sprays)	1. Calyx spray	When most petals have fallen.
	2. First cover spray	3 weeks after 1.
	3. Second cover spray	8 to 10 days after 2.
	4. Third cover spray	16 to 20 days after 2.
	5. Fourth cover spray	24 to 30 days after 2.
	6. Fifth cover spray	6 to 7 weeks after 2.
	7. Sixth cover spray	10 or 11 weeks after 2.

WHEN TO SPRAY PEARS.

Pears ordinarily do not become as wormy as apples, particularly when interplanted with them, the moths showing a preference for the apples. Where solid plantings of pears are made, the fruit often becomes decidedly wormy unless properly sprayed. In all cases, a calyx spray should be applied. As the pear calyces do not close rapidly, there is more time in which to apply this spray than in the case of apples.

Following the calyx spray, a cover spray should be given about four weeks after the petals have dropped. Where pears are interplanted with apples, these sprays may be applied at the same time the apples are being sprayed.

In the warmer sections, and where the worms are numerous, it is necessary to apply further cover sprays according to the seriousness of the infestation. Where the worms are unusually difficult to control, pears should be sprayed as often as apples. Bartletts or other early varieties should not be sprayed after the end of July, as they are usually harvested in August.

If only one spray is needed this may be applied at the time of the first cover spray for apples. This will act as a combined calyx and cover spray, because the calyx cups mostly remain open in pears until after this time (Table 2, schedule 1). If this one spray is insufficient, a calyx spray should be applied earlier, because pears are more subject to calyx worms than apples and need more protection in the calyx (Table 2, schedule 2).

In order to facilitate an even distribution of the spray over the smooth waxy surface of the pears and to prevent the objectionable blotching of the mature fruit, it is advisable to use a spreader in the cover sprays.

Table 2 suggests schedules for pears differing in the number of applications.

SPRAY SCHEDULES FOR PEARS.

TABLE 2.—*Codling moth spray schedules for pears in the Pacific Northwest.*

Schedule.	Spray.	Time of application.
Schedule 1 (1 spray)	1. Combined calyx and cover spray	Just before worms begin to hatch.
Schedule 2 (2 sprays)	1. Calyx spray 2. Cover spray	When most petals have fallen. 3 or 4 weeks after 1.
Schedule 3 (3 sprays)	1. Calyx spray 2. First cover spray 3. Second cover spray	When most petals have fallen. 3 weeks after 1. 2 weeks after 2.
Schedule 4 (4 sprays)	1. Calyx spray 2. First cover spray 3. Second cover spray 4. Third cover spray	When most petals have fallen. 3 weeks after 1. 2 weeks after 2. 7 or 8 weeks after 2.
Schedule 5 (5 sprays)	1. Calyx spray 2. First cover spray 3. Second cover spray 4. Third cover spray 5. Fourth cover spray	When most petals have fallen. 3 weeks after 1. 2 weeks after 2. 7 or 8 weeks after 2. 2 or 3 weeks after 4.

CONCISE DIRECTIONS FOR SPRAYING.

Own a good spraying outfit and keep it in good mechanical condition. It pays.

Have sufficient pressure to break the spray into a fine mist. If your outfit will not do this with the nozzles you are using, put in disks with smaller holes, or use fewer nozzles. Replace the disks as the holes become worn.

Use any standard brand of lead arsenate, 2 pounds of powder to 100 gallons of water, or 3 pounds in early sprays. The use of a spreader is advisable.

Never omit the calyx spray. Put it on as soon as the petals have fallen. Spray very thoroughly and fill every calyx cup.

Apply as many cover sprays as necessary. Get expert advice as to the number necessary and when to apply them. If this is not available, use the recommendations contained in this bulletin. Be particularly thorough with the cover sprays for the first brood. Spray the entire surface of each fruit. Remember there is fruit in the center of the tree and in the top.

Do not apply very late sprays or use more than the recommended proportions of lead arsenate. Either course may result in objectionable spotting of fruit at harvest time.

Hold to your spray schedule. Do not let other orchard operations interfere with it.

REMOVING SPRAY RESIDUE.

The removal of excessive spray residues is obligatory, and must be done by the grower or shipper. Satisfactory methods have been

worked out and suitable machines are available for carrying out this process. Removal is accomplished by carrying the fruit through the machine, spraying or flooding it with an acid or alkaline wash which dissolves off most of the spray material, and rinsing and drying it before it is packed.

In most instances this removal of the residue is not difficult to accomplish. Care should be exercised by the grower, however, to avoid spray schedules which may result in excessive residues.[5]

COMBINATION SPRAYING FOR THE CODLING MOTH, POWDERY MILDEW,[6] AND SCAB.

Prepared in cooperation with D. F. FISHER, *Principal Horticulturist. Bureau of Plant Industry*

Apple powdery mildew is found on apples practically throughout the Pacific Northwest, while scab occurs only in the more humid sections such as west of the Cascade Mountains and in the hilly regions of eastern Washington and Idaho. As these two fungous diseases are combatted by spraying at approximately the same time as the spraying for the codling moth, it is very often convenient to combine the materials used and spray them on the trees together. This applies particularly to the calyx spray and the first two cover sprays.

A weak lime-sulphur solution (see Tables 3 and 4) is the fungicide most often used to control mildew and scab. It is entirely safe and practicable to mix lime-sulphur and lead arsenate if certain precautions are observed. In mixing the sprays the lime-sulphur should be put in while the tank is being filled, and the arsenical added just before beginning to spray and while the spray solution is being vigorously agitated. It is also well to turn the nozzles into the tank for a minute or two before beginning to spray, to insure uniform mixing.

Because of a chemical reaction which occurs in the mixture, the combined spray should be used at once and not allowed to stand in the tank for several hours. This procedure will insure against the accumulation in the tank of a heavy black precipitate that is the result of the reaction and that might give trouble in the valves and screens of the machine. The reaction may be retarded by adding to the 200-gallon tank the milk of lime obtained by slaking 8 pounds of quicklime, but this is not necessary if the material is sprayed out promptly. A spreader, preferably casein,[7] should always be used in mildew spraying to effect a uniform covering of the foliage. This spreader will also retard the reaction between the lime-sulphur and the lead arsenate if put into the tank before either of the other ingredients is added.

In spraying for mildew or scab, more material must be used than where the codling moth alone is concerned, since both sides of the leaves must be thoroughly covered with the spray. The proper times to use the fungicides are indicated in Tables 3 and 4.

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[5] For a discussion of spray residue removal see U. S. Dept. Agr. Circular 59, Removal of Spray Residue from Apples and Pears in the Pacific Northwest. More detailed information may be obtained from the Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

[6] For a full discussion of apple powdery mildew and fungicides to use for it, see Farmers' Bulletin 1120, Control of Apple Powdery Mildew.

[7] Soap spreaders can not be used with lime-sulphur.

COMBINED SPRAY SCHEDULES FOR THE CODLING MOTH, POWDERY MILDEW, AND SCAB.

In Table 3 is given a spray schedule for the control of the codling moth in the arid irrigated sections of the Pacific Northwest. Recommendations for mildew spraying are added *in italics*. The first column in each section gives the character of the application and the time to apply it. The second column specifies the material to be used and the quantity, while the third column shows the pest to be controlled by each material. The pink spray is for the mildew alone. If the interval between the calyx spray and the first cover spray is more than three weeks, which may occur in cool wet seasons, a special mildew spray should be applied two weeks after the calyx spray, using the same spray as for the pink spray.

It is impossible to give special spray schedules for each section of the region covered by this bulletin, but the one given in Table 3 will be used by the majority of growers in the arid regions. There may be certain sections or certain orchards, as already explained, situated so favorably that fewer applications will suffice. On the other hand, growers in the warmest parts of the Northwest, or in very wormy localities, may find it necessary to apply two cover sprays for the second brood of worms instead of one, as indicated in schedule 6, Table 1.

Table 4 gives a spray schedule to be used wherever scab is of sufficient importance to warrant control measures. This applies to the regions west of the Cascade Mountains, except the Rogue River Valley, and to some of the more humid sections in the eastern part of the region covered by this bulletin. In some of these districts it will not be necessary to apply more than one or two sprays for the codling moth, though more may be required to control scab.

TABLE 3.—*Combined codling moth and powdery mildew spray schedule for the arid sections of the Pacific Northwest*

Application and time.	Materials.	Pest controlled.
Pink spray: Apply just before the blossoms open.	*Lime-sulphur, 1 to 50, or iron sulphide*	*Apple powdery mildew.*
Calyx spray: Apply when most petals have fallen.	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water.	Codling moth.
	Lime-sulphur, 1 to 50; or iron sulphide	*Apple powdery mildew.*
First cover spray: Apply just before first worms are hatching. (About 3 weeks after calyx spray.)	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water.	Codling moth.
	Lime-sulphur, 1 to 50; or iron sulphide	*Apple powdery mildew.*
Second cover spray: Apply 8 to 10 days after first cover spray.	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water.	Codling moth.
	Lime-sulphur, 1 to 50; or iron sulphide;[1] *or ammoniacal copper carbonate.*[2]	*Apple powdery mildew.*
Third cover spray: Apply 16 to 20 days after first cover spray.	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water.	Codling moth.
Fourth cover spray: Apply 6 to 7 weeks after first cover spray.	——do——	Do.

[1] Use if the infection is severe or the crop light.
[2] Use where the danger of burning the fruit is to be avoided.

TABLE 4.—*Combined codling moth, scab, and powdery mildew spray schedule for the humid sections of the Pacific Northwest*

Application and time.	Materials.	Pest controlled.
First cluster-bud spray: Apply when buds are bursting.	*Lime-sulphur, 1½ to 50*	*Scab.*
Pink spray: Apply just before the blossoms open.	do	*Scab and mildew.*
Calyx spray: Apply when most petals have fallen.	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water. *Lime-sulphur, 1½ to 50*	Codling moth. *Scab and mildew.*
10-day spray: Apply 10 to 14 days after calyx spray.	*Lime-sulphur 1½ to 50*	Do.
First cover spray: Apply just before first worms are hatching (3 or 4 weeks after calyx spray).	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water. *Lime-sulphur, 1½ to 50*	Codling moth. *Scab and mildew.*
Second cover spray:[1] Apply 2 weeks after first cover spray.	Lead arsenate, powder, 1 pound, or paste, 2 pounds, to 50 gallons of water.	Codling moth.
Third cover spray: Apply 6 or 7 weeks after first cover spray.	do	Do.

[1] Apply this spray if codling moth infestation is severe or the season unusually warm.

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